***ASJ**: International Journal of Health, Safety and Environments (IJHSE)*
Vol. 04 (04) 17 November, 2018, Pp. 269-279
www.academiascholarlyjournal.org/ijhse/index_ijhse.htm
ISSN: 2360-9311©Academia Scholarly Journals
Indexed In: Directory of Research Journals Indexing - http://www.drji.org
Also Available@; Internet Archive@Oboh et al.
Open access

Full Length Research

Environmental Impact of Abattoir Waste Discharge on Groundwater Quality in Osubi Community, Delta State, Nigeria

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Accepted November 10, 2018

Increasing anthropogenic activities have impacted negatively on groundwater quality. The study examines the groundwater quality around the abattoir in Osubi community. Water samples were collected monthly from three (3) boreholes located at different distances from the abattoir for a period of six months. Twenty-five (25) physico–chemical parameters were analyzed using standard procedures, and the results were analysed using descriptive and inferential statistics. Results showed that except for elevated levels of Turbidity, Total suspended Solids (TSS), Biochemical Oxygen Demand (BOD) and Magnesium; concentrations of other physico-chemical parameters were within acceptable limits of NSDWQ and WHO. The abattoir was seen to influence the concentrations of these parameters significantly across the three borehole locations with decreasing concentrations relative to distance from the abattoir, except for copper, lead, cadmium, vanadium, chromium and total hydrocarbon. Although, Water Quality Index (WQI) revealed good water quality suitable for human consumption and use for other domestic purposes, there is need to monitor and ensure proper disposal of waste at the abattoir to forestall further groundwater contamination.

Keywords: Abattoir, Waste, Water quality, Groundwater, Osubi, Nigeria.

INTRODUCTION

Abattoir activities have been identified as a source of pollution and reported to impact negatively on soil, natural water resources and the entire environment (Adesemoye et al., 2006). Abattoir wastes usually are multi-dimensional, mainly organics containing fat, grease, hair, feathers, grit, flesh, manure, and undigested feed, blood, bones and process water (Coker et al., 2001; Nafarnda et al., 2006). These are released in the soil as natural sink and subsequently leached out into the groundwater by percolation. Abattoir effluents whether it reaches the water body through a point source or non-point source reduces oxygen in water, produce excessive microbial growth causing unpleasant taste and odours of water from the source (Mittal, 2004; Ojekunle and Lateef, 2017). In Nigeria, nearly every town and community is provided with an abattoir with poor waste management facilities. Several studies have reported the impact of abattoir on the groundwater quality in various locations (Ogbonnaya, 2008; Ahmed et al., 2016; Ojekunle and Lateef, 2017); as wells within the vicinity of abattoirs which serve as source of water to the abattoir users was monitored and found to be polluted by effluent from the abattoir

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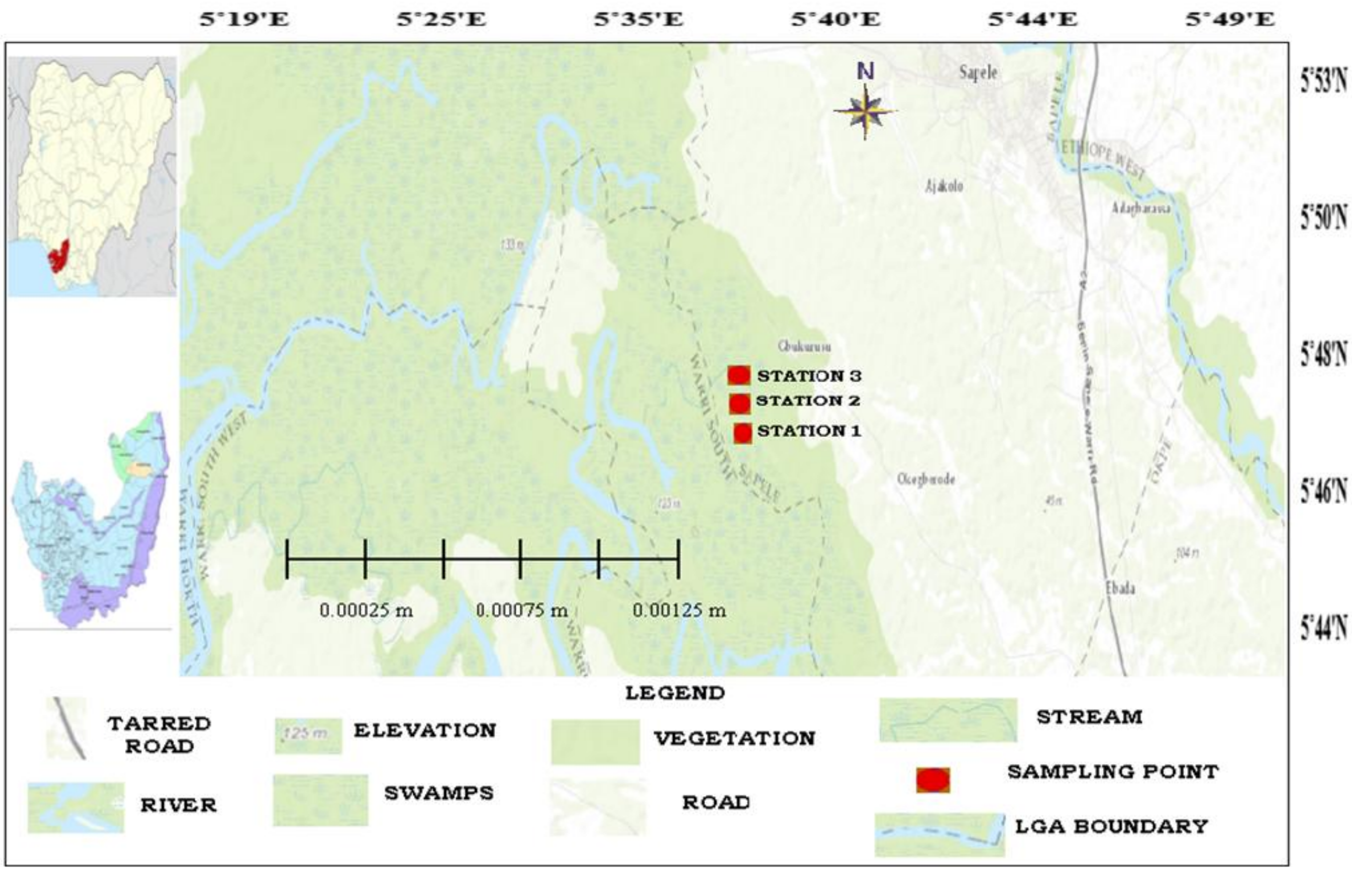

Figure 1. Map of study area showing borehole locations in Osubi community, Okpe Local Government Area, with inserts (Delta State, Nigeria.).

and constitute health risk for users of the wells (Oyinlola and Jegede, 2004).

The Osubi community in Warri has witnessed rapid urbanization in recent times, which has made the conventional water supply grossly inadequate, thereby resulting to the use of underground water in boreholes by majority of the inhabitants. However, with the health implications associated with the use of water from boreholes located in the abattoir and its surrounding for drinking and domestic purposes, this study has become very imperative. Present study evaluates the impact of abattoir wastes on groundwater quality of selected boreholes located close to the abattoir; assess the suitability of the water for drinking and domestic use with reference to national and international standards/guidelines; and determine the impact of the abattoir a point source of groundwater pollution in the study area.

MATERIALS AND METHODS

Study area

Osubi community (05° 35′ 50″ N, 05° 49′ 10″ E) is situated in Okpe Local Government Area, Delta State. It has an estimated land area of about 500km^2 (Figure 1). It has as a tropical climate with significant rainfall (March to October) in most parts of the year. The short dry season (November to February) has little effect on the overall climate. The average annual temperature is 26.6 °C while annual rainfall is 2,638 mm. The territory is made up essentially of lowland – arable forests and vegetation upland with swampy and mangrove forests inland. The subsurface geology of the area indicates that it lies within the Niger Delta Basin containing the Oligocene Benin and the Eocene

Ogwashi/Asaba aquifers. Aquifers are composed of alternating layers of gravels, sands, silts and clays, and recharged by direct infiltration of rainfall (Olobaniyi et al., 2007; Akpoborie et al., 2011). It is a flourishing centre for trade and other economic activities due to its strategic location and increasing population. Situated markets lack physical planning, as such wastes are indiscriminately dumped within and around the market (especially abattoir waste), causing serious health challenges.

Sampling locations

This research employed purposive and supervised sampling in the selection of the three (3) borehole locations for the study. Borehole 1 (BH 1) (05^o 34’ 36.14’’ N, 005^o 48’ 0.10’’ E) is situated within the abattoir, which is about 50 metres away from the market. Borehole 2 (BH 2) (05^o 34’ 43.32’’ N, 005^o 48’ 11.14’’ E) and Borehole 3 (BH 3) (05^o 34’ 46.40’’ N005^o 48’ 14.44’’ E) are situated within the residential localities at a distance of 100 metres and 150 metres from the abattoir respectively. Water from these boreholes is used for drinking, cooking, bathing and for other domestic purposes.

Sampling frequency, collection and physico-chemical analysis

Water sampling was carried out monthly for a period of six months from May to October 2016. In situ measurements were carried out for water temperature, hydrogen ion concentration (pH) and electrical conductivity (EC) at all stations. Water samples were collected using pre – washed 1 litre plastic containers, placed in a cooler box and then taken to the laboratory for analysis. Turbidity, Total suspended Solids (TSS), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Sodium, Potassium, Calcium, Magnesium, Sulphate, Nitrate, Phosphate and Chloride were analysed according to outlined procedures in the Standard Methods for the Examination of Water and Wastewater (APHA, 1998). Metal ions of Copper, Lead, Cadmium, Iron, Zinc, Manganese, Vanadium, Chromium and Total Hydrocarbon (THC) were analysed using the Atomic Absorption Spectrometer.

Results were compared with permissible limits of the Nigerian Standard for Drinking Water Quality (SON, 2007) and the World Health Organisation Standards (WHO, 2011). Statistical analyses were computed using Microsoft excel and Statistical Package for Social Sciences (SPSS 16.0). Comparisons between sampling points were carried out using the Analysis of Variance (ANOVA) and the source of significant difference located using Duncan’s Multiple Range (DMR) Test.

Water quality index (WQI)

Water Quality Index (WQI) was calculated using the Weighted Arithmetic Mean method as described by Chauhan and Singh (2010) and Shweta et. al., (2013).

The calculation of WQI was made by using the following equations:

$$WQI = \frac{\sum Q_i W_i}{\sum W_i}$$

The quality rating scale (Qi) for each parameter is calculated by using the expression:

$$Q_i = 100 \left[\frac{V_i - V_0}{S_i - V_0}\right]$$

Where,

V_i = Estimated Concentration of the i th parameter of interest in the analysed water.

V_o = The ideal value of the i th parameter in pure water. V_o = 0 (except pH = 7.0; and DO = 14.6 mg/l)

S_i = Recommended Standard value of the i th parameter

The unit weight (Wi) for each water quality parameter is calculated by using the following formula:

$$W_i = \frac{K}{S_i} \quad , \quad K = \frac{1}{\sum\left(\frac{1}{S_i}\right)}$$

Where,

K = proportionality constant and can also be calculated by using the following equation:

$$W_i = \frac{K}{S_i} \quad , \quad K = \frac{1}{\sum\left(\frac{1}{S_i}\right)}$$

The rating of water quality according to this WQI is given in Table 1.

RESULTS

The results of the physico-chemical parameters of

Table 1. Water Quality Rating as per Weighted Arithmetic Mean Method (Shweta et al., 2013)

WQI Value	Rating of Water Quality	Grading
0 – 25	Excellent water quality	A
26 – 50	Good water quality	B
51 – 75	Poor water quality	C
76 – 100	Very Poor water quality	D
Above 100	Unsuitable for drinking purpose	E

the studied groundwater from selected boreholes are presented in Table 2.

Physico-chemical parameters

The mean water temperature was lowest (28.06 ^oC) at BH 1 and highest (28.28 ^oC) at BH 3. There was very little variation in water temperature across the sampled boreholes, with the lowest value (27.40 ^oC) and the highest value (29.20 ^oC) recorded in the month of May and October respectively at BH 2. The pH values revealed that the water was acidic to slightly alkaline, with a range of 6.13 – 7.85. There was a high significant difference ($p < 0.01$) in the pH values across the three boreholes with BH 1 significantly higher than BH 2 and BH 3. The Electrical conductivity (EC) values ranged from 11.58 µS/cm (BH 3) to 525.6 µS/cm (BH 1). Temporal and spatial analysis showed inconsistency in conductivity variation, with BH 1 recording highest values across the months. There was a very high significant difference ($p < 0.001$) in the pH values across the three boreholes with BH 1 significantly higher than BH 2 and BH 3.

The mean turbidity values ranged from 0.72 NTU (BH 2) to 37.53 NTU (BH 1), with BH 1 recording very high significant ($p < 0.001$) values from BH 2 and BH 3. Total suspended solids (TSS) followed the same variation and very high significant trend as turbidity with the lowest mean value (0.72 mg/l) at BH 2 and highest mean value (32.67 mg/l) at BH 1. The pattern of variation of Total dissolved solids (TDS) across all boreholes was similar to that of TSS, as TDS mean values ranged between 36.98 mg/l and 228.5 mg/l, with BH 3 and BH 1 having the lowest and highest respectively.

The mean Dissolved oxygen (DO) was generally low with values varying between 0.40 mg/l (BH 1) and 5.90 mg/l (BH 2). DO values showed very high significant difference ($p < 0.001$) attributed to very low values recorded at BH 1. The Biochemical Oxygen Demand (BOD) was lowest at BH 2 with a mean of 1.40 mg/l, and highest at BH 1 with a mean of 7.70 mg/l. The highest value (9.20 mg/l) was recorded in May at BH 1 and the lowest (0.90 mg/l) in August at BH 2. BOD values were highly significant ($p < 0.001$) between the studied locations, attributed to very high values recorded at BH 1.

Sodium concentration of water samples was lowest (0.52 mg/l) at BH 2 in the month of July, and highest (58.12 mg/l) at BH 1 in May, with BH 1 recording highest values across the months. There was significant difference ($p < 0.05$) in sodium concentration values across the locations, with BH 1 recording higher values than BH 2 and BH 3. The mean potassium value was lowest (0.44 mg/l) in BH 3 and highest (2.27 mg/l) in BH 1, with significant difference ($p < 0.05$) in values across the locations, with BH 1 recording higher values than BH 2 and BH 3. Variation in mean calcium concentration values ranged from 0.24 mg/l in BH 3 to 0.89 mg/l in BH 1; with highest value of 1.72 mg/l was recorded in May (BH 1) and lowest value of 0.09 mg/l was recorded in September (BH 3), with high significant difference ($p < 0.01$) across the study locations, attributed to very high values recorded at BH 1. The mean magnesium concentration ranged from 0.28 mg/l (BH 2) to 1.70 mg/l (BH 1), with highest values recorded at BH 1 throughout the study, with high significant difference ($p < 0.01$) across the locations, attributed to very high values recorded at BH 1.

Table 2. Summary of the Physical and Chemical Parameters of Groundwater from Sampling Stations in, Delta State. from October, 2016 to March, 2017.

Parameter	BH 1			BH 2			BH 3			P - Value	Limits	
	Mean ± SD	Min	Max	Mean ± SD	Min	Max	Mean ± SD	Min	Max		NSDWQ 2007	WHO 2011
Water Temp. (^{0}C)	28.07 ± 0.186	27.60	28.60	28.22 ± 0.279	27.40	29.20	28.28 ± 0.217	27.60	29.10	$p > 0.05$	30 - 35	27 - 40
pH	7.44 ± 0.113^{a}	7.12	7.85	6.75 ± 0.130^{b}	6.13	6.98	6.72 ± 0.109^{b}	6.35	7.07	$p < 0.01$	6.5 - 8.5	6.5 – 8.5
EC	426.74 ± 30.22^{a}	318.60	525.60	68.52 ± 14.88^{b}	15.50	104.40	67.37 ± 16.12^{b}	11.58	113.40	$p < 0.001$	1000	1000
Turbidity (NTU)	37.53 ± 2.860^{a}	31.20	49.90	0.72 ± 0.240^{b}	0.10	1.50	2.07 ± 0.811^{b}	0.10	4.80	$p < 0.001$	5	3
TSS (mg/l)	32.67 ±1.626^{a}	28.00	38.00	0.72 ± 0.314^{b}	0.10	2.00	1.20 ± 0.461^{b}	0.10	3.00	$p < 0.001$	0	N/A
TDS (mg/l)	228.54 ± 9.00^{a}	161.50	289.80	37.46 ± 8.423^{b}	7.80	57.50	36.99 ± 9.11^{b}	5.80	62.40	$p < 0.001$	500	500
DO (mg/l)	0.90 ± 0.014^{b}	0.40	1.40	5.50 ± 0.169^{a}	4.80	5.90	5.08 ± 0.149^{a}	4.40	5.40	$p < 0.001$	7.5	5.0
BOD (mg/l)	7.70 ± 0.392^{a}	6.80	9.20	1.40 ± 0.230^{b}	0.90	2.50	1.63 ± 0.286^{b}	1.10	3.00	$p < 0.001$	0.05	0.05
Sodium (mg/l)	19.98 ± 7.75^{a}	9.73	58.12	3.06 ± 1.18^{b}	0.52	7.86	2.56 ± 0.988^{b}	0.60	6.61	$p < 0.05$	200	-
Potassium (mg/l)	2.27 ± 0.754^{a}	0.60	5.80	0.58 ± 0.265^{b}	0.13	1.85	0.44 ± 0.143^{b}	0.14	1.06	$p < 0.05$	-	-
Calcium (mg/l)	0.89 ± 0.174^{a}	0.58	1.72	0.30 ± 0.077^{b}	0.11	0.65	0.24 ± 0.078^{b}	0.09	0.60	$p < 0.01$	-	-
Magnesium (mg/l)	1.70 ± 0.398^{a}	0.76	3.34	0.28 ± 0.191^{b}	0.05	1.23	0.32 ± 0.175^{b}	0.01	1.16	$p < 0.01$	-	0.1
Sulphate (mg/l)	15.86 ± 3.299^{a}	1.86	21.99	1.91 ± 0.386^{b}	1.04	3.51	0.91 ± 0.15^{b}	0.28	1.20	$p < 0.001$	100	100
Nitrate (mg/l)	1.32 ± 0.162^{a}	0.95	1.91	0.36 ± 0.053^{b}	0.15	0.51	0.30 ± 0.029^{b}	0.21	0.40	$p < 0.001$	50	50
Phosphate (mg/l)	0.36 ± 0.021^{a}	0.28	0.42	0.03 ± 0.081^{b}	0.01	0.06	0.03 ± 0.007^{b}	0.01	0.06	$p < 0.001$	5	10
Chloride (mg/l)	127.91 ± 12.60^{a}	78.18	162.09	17.44 ± 3.267^{b}	4.50	28.51	14.81 ± 2.63^{b}	4.50	24.56	$p < 0.001$	250	250
Copper (mg/l)	0.00 ± 0.00	0.00	0.00	0.00 ± 0.00	0.00	0.00	0.00 ± 0.00	0.00	0.00	-	1.0	2.0
Lead (mg/l)	0.001 ± 0.00	0.001	0.001	0.001 ± 0.00	0.001	0.001	0.001 ± 0.00	0.001	0.001	-	0.01	0.01
Cadmium (mg/l)	0.001 ± 0.00	0.001	0.001	0.001 ± 0.00	0.001	0.001	0.001 ± 0.00	0.001	0.001	-	0.003	0.003
Iron (mg/l)	1.41 ± 0.239^{a}	0.73	2.21	0.32 ± 0.126^{b}	0.10	0.94	0.26 ± 0.124^{b}	0.08	0.88	$p < 0.001$	0.3	0.1
Zinc (mg/l)	0.17 ± 0.026^{a}	0.11	0.26	0.06 ± 0.020^{b}	0.01	0.13	0.04 ± 0.014^{b}	0.013	010	$p < 0.01$	3.0	1.5

Table 2. Contd.

Manganese (mg/l)	0.05 ± 0.009 [a]	0.03	0.08	0.04 ± 0.008 [a]	0.02	0.07	0.03 ± 0.006 [b]	0.01	0.04	$p < 0.05$	0.05 -0.5	-
Vanadium (mg/l)	0.05 ± 0.00	0.05	0.05	0.05 ± 0.00	0.05	0.05	0.05 ± 0.00	0.05	0.05	$p > 0.05$	0.01	-
Chromium (mg/l)	0.05 ± 0.00	0.05	0.05	0.05 ± 0.00	0.05	0.05	0.05 ± 0.00	0.05	0.05	$p > 0.05$	0.05	0.05
THC (mg/l)	0.05 ± 0.00	0.05	0.05	0.05 ± 0.00	0.05	0.05	0.05 ± 0.00	0.05	0.05	$p > 0.05$	1.0	-
Total coliform	33.33 ± 2.72 [a]	24.00	42.00	11.67 ± 1.59 [b]	7.00	17.00	10.67 ± 2.31 [b]	4.00	18.00	$p < 0.001$	-	10

Note: p < 0.05 – Significant; p > 0.05 – Not Significant; p < 0.01 – Highly significant; p < 0.001 – Very highly significant; Similar superscript indicates no significant difference, Unsimilar superscript indicates significant difference.

Sulphate concentration was generally low in all locations except at the abattoir (BH 1), with mean values range of 0.91 mg/l (BH 3) to 15.86 mg/l (BH 1) and BH 1 recording highest values throughout the study. The pattern of variations for Nitrate across the locations was similar to that of Sulphate. As mean nitrate levels ranged from 0.29 mg/l (BH 3) to 1.32 mg/l (BH 1), and a very high significant difference ($p < 0.001$) in nitrate values across the locations, attributed to very high values recorded at BH 1. Similarly, Phosphate and Chloride showed similar variation pattern with Sulphate. As mean phosphate value ranged from 0.027 mg/l (BH 2 and BH 3) to 0.363 mg/l (BH 1); and mean chloride content varied from 14.81 mg/l (BH 3) to 127.91 mg/l (BH 1). There was a very high significant difference ($p < 0.001$) in phosphate and chloride values across the locations, with BH 1 very significantly different from BH 2 and BH 3.

Copper was not detected in water samples collected from all locations throughout the study. The mean iron content was lowest (0.26 mg/l) in BH 3 and highest (1.41 mg/l) in BH 1, with a very high significant difference ($p < 0.001$) in iron values across the locations, with BH 1 recording higher values than BH 2 and BH 3. The mean potassium value was lowest (0.44 mg/l) in BH 3 and highest (2.27 mg/l) in BH 1, with significant difference ($p < 0.05$) in values across the locations, with BH 1 recording higher values than BH 2 and BH 3. Variation in mean calcium concentration values ranged from 0.24 mg/l in BH 3 to 0.89 mg/l in BH 1; with highest value of 1.72 mg/l was recorded in May (BH 1) and lowest value of 0.09 mg/l was recorded in September (BH 3), with high significant difference ($p < 0.01$) across the study locations, attributed to very high values recorded at BH 1.

The mean concentration of zinc ranged from 0.042 mg/l (BH 3) to 0.168 mg/l (BH 1), with highest value of 0.258 mg/l was recorded in October at (BH 1) and lowest value of 0.013 mg/l was recorded in August (BH 2 and BH 3), with high significant difference ($p < 0.01$) across the study locations, attributed to very high values recorded at BH 1. The mean manganese concentration ranged from 0.025 mg/l (BH 3) to 0.050 mg/l (BH 1), with BH 1 and BH 2 significantly different ($p < 0.05$) from BH 3 in values throughout the study. Lead and Cadmium concentrations were very low throughout the study; with a temporal and spatial consistent value of 0.001 mg/l recorded for them in all three boreholes studied. Similarly, Vanadium, Chromium and Total hydrocarbon (THC) concentrations recorded a consistent value of 0.050 mg/l in all the months of study and across all locations.

Table 3. Water Quality Index (WQI) for Borehole 1 (BH 1), Borehole 2 (BH 2) and Borehole 3 (BH 3).

Parameter	NSDWQ Limits (S_i)	1/Si	K	BH 1				BH 2				BH 3			
				Test Result	W_i	Q_i	$[(W_i)(Q_i)]$	Test Result	W_i	Q_i	$[(W_i)(Q_i)]$	Test Result	W_i	Q_i	$[(W_i)(Q_i)]$
pH	6.5 - 8.5	0.16	0.0016	7.44	0.0103	-88	-0.904	6.75	0.0103	50	0.514	6.722	0.0103	55.6	0.571
EC	1000	0.001	0.0016	426.74	1.58	42.674	67.424	68.52	1.58	6.85	10.826	67.37	1.57999	6.737	10.64
Turbidity	5	0.2	0.0016	37.53	0.008	750.6	5.9297	0.717	0.008	14.34	0.1133	2.067	0.0079	41.34	0.327
TDS	500	0.002	0.0016	228.54	0.790	45.708	36.109	37.46	0.789	7.49	5.9186	36.99	0.790	7.398	5.844
DO	7.5	0.133	0.0016	0.9	0.0119	192.96	2.287	5.5	0.012	128	1.5188	5.083	0.0119	134.04	1.588
BOD	0.05	20	0.0016	7.7	7.9E-05	15400	1.217	1.4	7.9E-05	2800	0.2212	1.633	7.9E-05	3266	0.258
Sulphate	100	0.01	0.0016	15.86	0.158	15.86	2.506	1.91	0.158	1.91	0.3018	0.91	0.158	0.91	0.144
Nitrate	50	0.02	0.0016	1.32	0.079	2.64	0.209	0.355	0.079	0.71	0.0561	0.299	0.079	0.598	0.047
Phosphate	5	0.2	0.0016	0.36	0.0079	7.2	0.057	0.027	0.0079	0.54	0.0043	0.027	0.0079	0.54	0.004
Chloride	250	0.004	0.0016	127.9	0.395	51.16	20.21	17.44	0.395	6.98	2.756	14.18	0.395	5.672	2.240
Copper	1	1	0.0016	0	0.0016	0	0	0	0.0016	0	0	0	0.0016	0	0
Lead	0.01	100	0.0016	0.001	1.58E-05	10	0.00016	0.001	1.58E-05	10	0.00016	0.001	1.58E-05	10	0.00016
Cadmium	0.003	333.33	0.0016	0.001	4.74E-06	33.33	0.00016	0.001	4.74E-06	33.33	0.00016	0.001	4.74E-06	33.33	0.00016
Iron	0.3	3.33	0.0016	1.411	0.00047	470.33	0.2229	0.315	0.00045	105	0.0498	0.264	0.00047	88	0.042
Zinc	3	0.33	0.0016	0.168	0.0047	5.6	0.0265	0.059	0.0047	1.97	0.009	0.042	0.0047	1.4	0.0067
Nickel	0.02	50	0.0016	0.0146	3.16E-05	73	0.0023	0.012	3.16E-05	60	0.0019	0.012	3.16E-05	60	0.0019
Vanadium	0.01	100	0.0016	0.05	1.58E-05	500	0.0079	0.05	1.58E-05	500	0.0079	0.05	1.58E-05	500	0.0079
Chromium	0.05	20	0.0016	0.05	7.9E-05	100	0.0079	0.05	7.9E-05	100	0.0079	0.05	7.9E-05	100	0.0079

Table 3. Contd.

Calcium	200	0.005	0.0016	0.893	0.316	0.45	0.1411	0.304	0.316	0.15	0.048	0.235	0.316	0.1175	0.037
Magnesium	150	0.007	0.0016	1.704	0.237	1.136	0.269	0.282	0.237	0.19	0.0446	0.315	0.237	0.21	0.0498
Sodium	200	0.005	0.0016	19.98	0.316	9.99	3.157	3.06	0.316	1.53	0.484	2.56	0.316	1.28	0.4045
THC	1	1	0.0016	0.05	0.0016	5	0.008	0.05	0.00158	5	0.0079	0.05	0.0016	5	0.0079
Manganese	0.5	2	0.0016	0.05	0.0008	10	0.008	0.037	0.00079	7.4	0.0059	0.025	0.0008	5	0.004
Water Temp.	35	0.029	0.0016	28.07	0.0553	80.2	4.435	28.22	0.0552	80.63	4.459	28.28	0.055	80.8	4.468
		$\sum$= 632.92			$\sum Wi$ = 3.974		$\sum$= 143.33		$\sum Wi$ = 3.974		$\sum$= 27.355		$\sum Wi$ = 3.974		$\sum$= 26.706
				WQI = 36.07				**WQI = 6.88**				**WQI = 6.72**			

Table 4. Summary of WQI values of sampled boreholes.

Borehole	WQI Value	Remark or Quality
BH 1	36.07	Good
BH 2	6.88	Excellent
BH 3	6.72	Excellent

Water Quality Index (WQI)

The WQI values ranged from 6.72 (BH 3) to 36.07 (BH 1) (Tables 3 - 6). Based on the standard classification (Table 1), groundwater from BH 2 and BH 3 are of excellent quality, while that of BH 1 is of good quality. A decreasing trend in WQI value from BH 1 to BH 3 was observed (Table 6).

DISCUSSION

Water quality assessment of a specific area or specific source utilizes the physical, chemical and biological parameters whose concentration values, when found to exceed permissible limits are deemed harmful to human health (WHO, 2011).

Water temperature can alter the physical and chemical properties of water. The observed water temperature (27.40 - 29.20°C) values were within the NSDWQ (2007) and WHO (2011) acceptable limits for drinking water. Similar values of 28.8 ^{0}C and 27.8 ^{0}C were reported by Magaji and Chup (2012); and Ojekunle and Lateef (2017) respectively in their various studies on groundwater within the surroundings of an abattoir. The observed pH values (6.13 – 7.85) indicate a slightly acidic to alkaline water for the sampled boreholes. Although these values were within the 6.5 to 8.5 acceptable limits for drinking water recommended by NSDWQ (2007) and WHO (2011); observed trend indicate decreasing pH values with distance from the abattoir with BH 1 situated within the abattoir recording the highest value. Ahmed et al. (2016) recorded a

mean pH of 7.14 for groundwater surrounding the abattoir in Keffi, Nigeria.

Electrical conductivity (EC) is a measure of the ion concentration in water or of the ability of water to transmit or pass an electric current (USEPA, 2010). Electrical conductivity values (11.58 – 50525.60 µS/cm) recorded in this study were within the acceptable limits of the NSDWQ and WHO. The significantly higher EC values in BH 1 can be attributed to the location of BH 1 in the abattoir, as other boreholes recorded decreasing values with distance from BH 1. Similarly, Ojekunle and Lateef (2017) reported EC range values of 184 - 631µS/cm, and values decreasing with distance from abattoir in their study within Abeokuta, Nigeria. Turbidity is the distortion of water clarity that is caused by suspended matter such as clay, silt, organic matter, planktons and some other microscopic organisms. The observed turbidity values (0.10 – 49.40 NTU) in this study exceeded the NSDWQ and WHO permissible limits for drinking water, with BH 1 recording the highest values and other boreholes recorded decreasing values with distance from BH 1.

Total suspended solids (TSS) is the total quantity measurement of all organic and inorganic suspended solid material per volume of water. The mean Total suspended solids (TSS) concentration (0.72 – 32.67 mg/l) observed across the borehole locations exceeded the NSDWQ (0.00 mg/l) and WHO permissible limits. Similar mean TSS value of 15.74 mg/l was recorded by Ojekunle and Lateef (2017) in their study. Total dissolved solids (TDS) is a measure of the amount of particulate solids in solution. Observed TDS values (5.80 – 289.80 mg/l) were below the NSDWQ and WHO permissible limits of 500 mg/l. However, BH 1 recorded significantly higher values which can be attributed to the abattoir/ anthropogenic activity around the location. A similar trend was reported by Ojekunle and Lateef (2017) in their study, as TDS values ranged from 75.00 to 323 mg/l, with values decreasing with distance from abattoir.

Dissolved Oxygen, (DO) measures the degree of pollution by organic matter, the destruction of organic matter as well as the self-purification capacity of the water body. The observed Dissolved Oxygen values (1.40 – 5.90 mg/l) were below the NSDWQ stipulated value of 7.5 mg/l but within the WHO value of 5 mg/l. Decreasing DO values were observed relative to distance from the abattoir. Water sources with high biochemical oxygen demand (BOD) values an indication of heavy microbial contamination (Agbabiaka and Sule, 2010). BOD values (0.90 – 9.20 mg/l) recorded in this study were all above the acceptable limits of 0.05 mg/l stipulated by NSDWQ and WHO, indicating that the borehole water was contaminated. Highest BOD values were recorded at BH 1.

The sodium concentrations (0.52 – 58.20 mg/l) were below the NSDWQ stipulated value of 200 mg/l. Decreasing sodium concentration values were observed relative to distance from the abattoir, with BH 1 recording the highest values and BH 3 recording the least values. The potassium concentrations (0.13 – 1.716 mg/l) in sampled boreholes were generally low, with BH 1 recording high values in comparison with BH 2 and BH 3. Also, study showed that potassium concentration was relative to distance from the abattoir. The observed calcium values (0.086 – 1.72 mg/l) in this study were below 60 mg/l, and therefore classified as soft water. Magnesium values (0.013 – 3.344 mg/l) in this study exceeded the WHO permissible limits (0.01 mg/l) for drinking water. Borehole 1 recorded significant high values for calcium and magnesium, while BH 2 and BH 3 recorded decreasing values with distance from BH 1. High values in BH 1 is attributed to the anthropogenic activity around the location.

The main effect of sulphate in water is on the taste. The concentration of sulphate recorded in this study (0.276 – 21.98 mg/l) was generally low and below the NSDWQ and WHO permissible limits. Borehole 1 however, showed significantly higher values which may be attributed to the anthropogenic activities in the location; other boreholes recorded decreasing values with distance from BH 1. Similar sulphate concentration values of 8.00 mg/l and 6.02 mg/l were reported by Ogbonnaya (2008) and Ahmed et al. (2016) respectively.

Nitrate is one of the most common groundwater contaminants in rural areas. It enters the groundwater through sewage and mineral deposits. Unpolluted natural waters usually contain very minute amount of nitrate, and an increase in nitrate in drinking water indicates leaching of nitrates from

nearby pit latrines and dumpsites (Purandara et al., 2003). Nitrate values (0.151 – 1.914 mg/l) recorded in this study are generally low and below the NSDWQ and WHO permissible limit of 50 mg/l, with BH 1 showing significant high values. Phosphate occurs naturally in rocks and is introduced into drinking as the water flows through the rocks. Excessive phosphate leads to reduction in dissolved oxygen and increase in eutrophication. The observed Phosphate values (0.007 – 0.42 mg/l) in this study were below the NSDWQ and WHO permissible limits of 5 mg/l and 10 mg/l respectively. However, BH 1 showed significantly higher phosphate concentrations than BH 2 and BH 3; which can be attributed to the high anthropogenic activity at the abattoir. Chloride values (4.50 – 162.09 mg/l) recorded in this study were below the NSDWQ and WHO permissible limits of 250 mg/l. Decreasing Chloride values were observed relative to distance from the abattoir, with BH 1 recording the highest value. Similar Chloride value of 168.50 mg/l was reported by Ahmed et al. (2016) for borehole water in the abattoir vicinity, in Keffi Nasarawa State.

Copper toxicity is the consequence of excess of copper in the body attributable to exposure to high levels of copper in drinking water or other environmental sources (Klaassen, 1995). Although the NSDWQ and WHO guideline concentration values for copper in drinking water is 1.0 mg/l and 2.0 mg/l respectively; a below detectible limit (BDL) of copper concentration was observed in this study. Similarly, Ogbonnaya (2008) reported a below detectible limit of copper concentrations for groundwater surrounding the abattoir in Minna. The observed mean iron concentrations (0.264 – 1.411 mg/l) exceeded the NSDWQ and WHO permissible limits of 0.3 mg/l and 0.1 mg/l respectively. Also, BH 1 showed very high significant ($p < 0.001$) high values and decreasing iron concentration values were observed relative to distance from the abattoir (BH 1). This high iron content may probably be attributed to influx of waste blood deposited on the ground which percolates through the soil. Similar values of 0.47 mg/l and 0.014 were reported by Ogbonnaya (2008) and Ahmed et al. (2016) respectively in their various studies.

Zinc imparts an undesirable astringent taste to water at concentrations exceeding 3mg/l (as $ZnSO_4$). Zinc concentration values (0.013 – 0.258 mg/l) recorded in this study was very low and within the NSDWQ and WHO permissible limits of 3.0 mg/l and 1.5 mg/l respectively. The significantly higher concentration of zinc observed in BH 1 can be attributed to high anthropogenic activities within the location of BH 1. The observed mean manganese values (0.025 – 0.050 mg/l) in this study were within the NSDWQ and WHO permissible limits for drinking water, with BH 1 recording the highest values and other boreholes recorded decreasing values with distance from BH 1. High values in BH 1 were attributed to the anthropogenic activities at the abattoir. A consistent concentration value of 0.05 mg/l was recorded for Vanadium, Chromium and Total hydrocarbon for all sampled boreholes throughout the study. These values were within their NSDWQ and WHO permissible limit respectively.

The application of water quality index (WQI) in this study has been profoundly useful in the assessment of the overall quality of the groundwater. The WQI of the sampled boreholes 36.07, 6.88 and 6.07 for BH 1, BH 2, and BH 3 respectively; indicate a trend of decreasing water quality from excellent (BH 3 and BH 3) to good (BH 2 and BH 3) with increasing proximity to the abattoir. It further gives credence to the abattoir been a point source of groundwater pollution.

CONCLUSION

Although, groundwater is the most readily obtainable and ideal source of fresh water due to its high quality with reference to safe consumption and the minimum treatment requirement in most cases, it is highly susceptible to pollution due to anthropogenic activities. Increasing demand for fresh water due to rapid population growth and industrialization, has made it imperative to regularly monitor groundwater quality and risk assessment in relation to anthropogenic activities such as abattoir operations. The main environmental concern in this study is the vulnerability of groundwater to abattoir waste pollution. Groundwater analysis revealed all physico – chemical parameters were within the acceptable limits of NSDWQ and WHO, except for elevated levels of turbidity, total suspended solids,

biochemical oxygen demand, magnesium and iron. Also, water parameters showed a correlation between their concentration and proximity to the abattoir with the borehole (BH 1) situated in the abattoir recording significant high values; an indication that the abattoir at present is a point source contaminant to groundwater in the study area indication. Although, Water Quality Index (WQI) revealed good water quality in the study area which is an indication that the water is suitable for human consumption and use for other domestic purposes; there is need to monitor and ensure proper disposal of waste at the abattoir to forestall further groundwater contamination.

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